LOW-ENERGY DIFFRACTION; A DIRECT-CHANNEL POINT OF VIEW: THE BACKGROUND

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Abstract. We argue that at low-energies, typical of the resonance region, the contribution from direct-channel exotic trajectories replaces the Pomeron exchange, typical of high energies. A dual model realizing this idea is suggested. While at high energies it matches the Regge pole behavior, dominated by a Pomeron exchange, at low energies it produces a smooth, structureless behavior of the total cross section determined by a direct-channel nonlinear exotic trajectory, dual to the Pomeron exchange.

In this paper we investigate the role of the low-energy background in diffractive processes. We follow the ideas of two-component duality [1], [2], by which the high-energy Pomeron exchange is dual to the low-energy background. In describing this background we use a dual amplitude with Mandelstam analyticity (DAMA) [3], where, contrary to narrow resonance dual models, nonlinear trajectories are not only allowed, but even required by their general properties. The asymptotic rise of the trajectories in DAMA is limited by the condition $|\frac{\alpha(s)}{\sqrt{s}\ln s}| \leq const, \quad s \to \infty$. The most popular trajectories, satisfying above condition, are square root type of trajectories [3] , used also in this work. Such trajectories have an upper bound on the real part of these trajectories, which results in the termination of the resonances on it. The maximal value of this real part is determined by the free parameters of the trajectories, that can be fitted to the resonance spectra.

An extreme case is that of an exotic trajectory, whose real part does not reach any resonance. Relevant examples are presented in this talk.

The (s,t)-term of DAMA is

$$D(s,t) = \int_0^1 dz \left(\frac{z}{g}\right)^{-\alpha(s')-1} \left(\frac{1-z}{g}\right)^{-\alpha(t')-1}, \tag{1}$$

where $s' = s(1-z)$, $t' = tz$, g is a parameter, $g > 1$, and s, t are the Mandelstam variables.

For $s \to \infty$ and $t = 0$ it has the following Regge asymptotic behavior

$$D(s,t) \approx \sqrt{\frac{2\pi}{\alpha_t(0)}} g^{1+a+ib} \left(\frac{s\alpha'(0) g \ln g}{\alpha_t(0)}\right)^{\alpha_t(0)-1}, \tag{2}$$

where $a = Re\ \alpha\Big(\frac{\alpha_t(0)}{\alpha'(0)\ln g}\Big)$ and $b = Im\ \alpha\Big(\frac{\alpha_t(0)}{\alpha'(0)\ln g}\Big)$.

The pole structure of DAMA is similar to that of the Veneziano model except that multiple poles may appear at daughter levels. The presence of these multipoles does not contradict the theoretical postulates. On the other hand, they can be removed without any harm to the dual model by means the so-called Van der Corput neutraliser. The procedure [3] is to multiply the integrand of (1) by a function $\phi(x)$ with the properties:

$$\phi(0) = 0, \quad \phi(1) = 1, \quad \phi^n(=0), \quad n = 1, 2, 3, ...$$

The function

$$\phi(x) = 1 - exp\left(\frac{-x}{1-x}\right),$$

for example, satisfies the above conditions and results [3] in a standard, "Veneziano-like" pole structure:

$$D(s,t) = \sum_n g^{n+\alpha_t(0)} \frac{C_n}{n - \alpha(s)}, \tag{3}$$

where C_n are the residues, whose form is fixed by the dual amplitude [3]:

$$C_n = \frac{\alpha_t(0)\Big(\alpha_t(0)+1\Big)...\Big(\alpha_t(0)+n+1\Big)}{n!}.$$

The pole term in DAMA is a generalization of the Breit-Wigner formula, comprising a whole sequence of resonances lying on a complex trajectory $\alpha(s)$. Such a "reggeized" Breit-Wigner formula has little practical use in the case of linear trajectories, resulting in an infinite sequence of poles, but it becomes a powerful tool if complex trajectories with a limited real part and hence a restricted number of resonances are used. If $Re\ \alpha(s) > 0$, equation (3) produces a sequence of Breit-Wigner resonances lying on the trajectory $\alpha(s)$.

Near the threshold, $s \to s_0$

$$D(s,t) \simeq \frac{g^2}{\alpha(s_0)} \left(\frac{1-\frac{s_0}{s}}{g}\right)^{-\alpha(s_0)} Im\ \alpha(s) \cdot$$

$$\cdot \left[\ln\left(\frac{x_1\,(1-\frac{s_0}{s})}{g}\right)\frac{Im\ \alpha(s_1)}{Im\ \alpha(s)} + \left(\frac{1}{\alpha(s_0)-\ln x_1}\right)\right] , \tag{4}$$

where $0 < x_1 < 1$ and $s_1 = s_0 + (s - s_0)(1 - x_1)$.

A simple model of trajectories satisfying the threshold and asymptotic constraints is a sum of square roots [3]

$$\alpha(s) = \alpha_0 + \sum_i \gamma_i \sqrt{s_i - s}. \tag{5}$$

The number of thresholds included depends on the model; while the lightest threshold gives the main contribution to the imaginary part, the heaviest one promotes the rise of the real part (terminating at the heaviest threshold).

A particular case of the model eq. (5) is that with a single threshold. Imposing an upper bound on the real part of this trajectory, $Re\ \alpha(s) < 0$, and inserting it to eqs. (1) or (3), we get an amplitude that does not produce resonances, since the real part of the trajectory does not reach $n = 0$ where the fist pole could appear. Its imaginary part instead rises indefinitely, contributing to the total cross section with a sooth background.

By using the dual model (1), we now calculate numerically the total cross sections

$$\sigma_t(s) = Im\ A(s, t = 0) , \tag{6}$$

where

$$A(s,t) = c\,(D(s,t) + D(u,t)) \tag{7}$$

and c is a normalization coefficient.

In this work we propose the following simplified model.[1] In the $t-$ channel we use a Pomeron trajectory of the form

$$\alpha_P(t) = 1.1 + 0.2t + 0.02(\sqrt{4m_\pi^2} - \sqrt{4m_\pi^2 - t}), \tag{8}$$

while the exotic $s-$ channel trajectory is

$$\alpha_E(s) = \alpha_0 + \alpha_1(\sqrt{s_0} - \sqrt{s_0 - s}). \tag{9}$$

In the Pomeron trajectory (8) the linear term mimics high-mass thresholds, important for the nearly exponential shape of the cone, while the lowest, $2m_\pi$ threshold is manifest as a "break" in the diffraction cone near 0.1 GeV^2.

By definition, the real part of the exotic trajectory should not pass through resonances; we tentatively set

$$Max\{Re\ \alpha_E(s)\} = \alpha_E(s_0) = \alpha_0 + \alpha_1\sqrt{s_0} = -1\ , \tag{10}$$

so that it does not reach $n = 0$, where summation in eq. (3) starts. For the lowest threshold in the exotic trajectory we choose $s_0 = (m_p + m_{J/\psi})^2$, with J/ψ photoproduction (or $J/\psi p$ scattering) in mind.

With this exotic trajectory the threshold behaviour of our amplitude is:

$$D(s,t) \sim (s - s_0)^{1/2 - \alpha_E(s_0)}\left[const + \ln(1 - s_0/s)\right] =$$

$$(s - s_0)^{3/2}\left[const + \ln(1 - s_0/s)\right]\ . \tag{11}$$

The only remaining free parameters are g, $\quad g > 1$ and the slope of the exotic trajectory α_1. For illustrative purposes we set $g = 10$ and $\alpha_1 = 0.2\ GeV^{-2}$.

With these inputs in hand, now we can calculate the total cross section for all values of s, from the threshold to the highest asymptotic values. By inserting the trajectories (8) (setting $t = 0$) and (9) into (1), we calculate the integrals numerically.

To see more clearly the contribution from the background, we have divided the cross section by its Regge asymptotics $\sim s^{0.1}$. The result, in arbitrary units, is shown in Fig. 1. One can clearly see a cusp between the flat asymptotic behavior and steep rise from the threshold. This is the contribution from the background, modeled by the contribution from the direct-channel exotic trajectory, amounting to about $10 - 12$ %.

The background plays an important role in the resonance region. Of particular practical interest is the correct account for the background in the

[1]Our earlier attempts to model the background (as well as resonance contributions) can be found in Refs. [4].

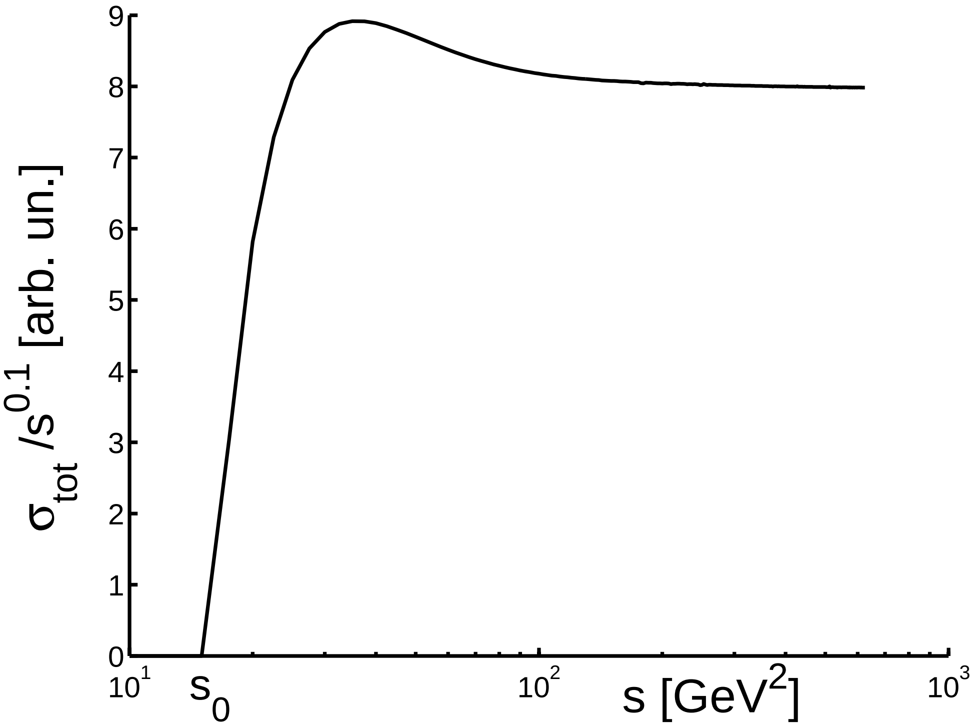

Figure 1. Purely diffractive contribution to the total cross section (in arbitrary units) calculated from DAMA, eq. (1), scaled to its Regge asymptotic behavior. The direct-channel exotic trajectory gives at low energies non-neglectable contribution (background), which could be seen as a cusp of $\sim 10 - 12$ %.

analysis of the JLab data on the electroproduction of nucleon resonances (see [5]).

The best testing field for this model is J/ψ scattering, where the exchange of secondary trajectories is forbidden and consequently no resonances are expected in the low energies region, dominated by the background, or the contribution of the direct-channel exotic trajectory. Since J/ψ total cross section is not measured directly, the relevant reaction is J/ψ photoproduction. In most of the papers on this subject, analyzing the HERA data on photoproduction (see e.g. [6] and refernces therein), the amplitude is assumed to be Regge behaved, eventually corrected by a threshold factor, but in any case ignoring the contribution from the background. The evaluation of the elastic cross section from (1) however involves also integration in t, thus making the calculations more complicated. This will be done in a forthcoming paper.

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